DETERMINING THE SPIN STRUCTURE OF THE PHOTON AT FUTURE COLLIDERS

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It is demonstrated that measurements of the spin asymmetry for di-jet production at future polarized colliders appear to be particularly suited for a first determination of the so far unmeasured parton densities of circularly polarized photons.

1 Δf^{γ}: Framework and Present Status

Nothing is known experimentally about the parton content of circularly polarized photons, defined by $\Delta f^{\gamma}(x,Q^2) \equiv f_{+}^{\gamma+}(x,Q^2) - f_{-}^{\gamma+}(x,Q^2)$, where $f_{+}^{\gamma+}$ ($f_{-}^{\gamma+}$) denotes the density of a parton f with helicity '+' ('−') in a photon with helicity '+', and the next round of spin experiments, Compass and Rhic, is not sensitive to these distributions either. The Δf^{γ} contain information different from that contained in the unpolarized ones, f^{γ}, and their measurement is vital for a *complete* understanding of the partonic structure of photons. It has been demonstrated [1] that measurements of the structure function g_1^{γ} and of di-jet spin asymmetries at a future polarized linear e^+e^- collider can provide valuable information about Δf^{γ}. Di-jet spin asymmetries at Hera running in a polarized collider mode, appear to be equally promising [2,3]. Here we will focus on two other recent proposals for a polarized ep collider: eRhic and THera. As in [1,2,3] we will exploit the predictions of two very different models for the Δf^{γ} [4], and study the sensitivity of di-jet production to these unknown quantities. In the first case ('maximal scenario') we saturate the positivity bound $|\Delta f^{\gamma}(x,Q^2)| \leq f^{\gamma}(x,Q^2)$ at a low input scale $\mu \simeq 0.6\,\mathrm{GeV}$, using the unpolarized GRV densities f^{γ} [5]. The other extreme input ('minimal scenario') is defined by a vanishing hadronic input at the scale μ. We limit ourselves to leading order (LO) QCD, which is entirely sufficient for our purposes; however both scenarios can be straightforwardly extended to next-to-leading order [6].

2 Δf^{γ}: Tests and Signatures

The generic expression for polarized *resolved* photoproduction of two jets with laboratory system rapidities η_1, η_2 and transverse momentum p_T reads in LO

$$\frac{d^3\Delta\sigma}{dp_T d\eta_1 d\eta_2} = 2p_T \sum_{f^e,f^p} x_e \Delta f^e(x_e,\mu_f^2) x_p \Delta f^p(x_p,\mu_f^2) \frac{d\Delta\hat{\sigma}}{d\hat{t}} \,, \qquad (1)$$

where $x_e \equiv p_T/(2E_e)\,(e^{-\eta_1}+e^{-\eta_2})$ and $x_p \equiv p_T/(2E_p)\,(e^{\eta_1}+e^{\eta_2})$. The Δf^p and Δf^e in (1) denote the spin-dependent parton densities of the proton and electron, i.e., photon, respectively, see [3]. The key feature of *di*-jet production is that a measurement of both jet rapidities allows for fully reconstructing the kinematics of the underlying hard subprocess and thus for determining $x_\gamma = x_e/y$ experimentally, with y being the fraction of the electron's energy taken by the photon. In this way it becomes possible to suppress the *direct* ($x_\gamma = 1$) contribution by, e.g., scanning different bins in x_γ, cf. [7].

Fig. 1 shows the di-jet spin asymmetries $A^{2-\mathrm{jet}} \equiv d\Delta\sigma/d\sigma$ at eRHIC ($\sqrt{s} = 100$ GeV) and THERA ($\sqrt{s} = 950$ GeV) for three bins in x_γ, using $\mu_f = p_T$, $0.2 \leq y \leq 0.85$ and similar cuts for $|\eta_1 - \eta_2|$ and $(\eta_1+\eta_2)/2$ as in [7].

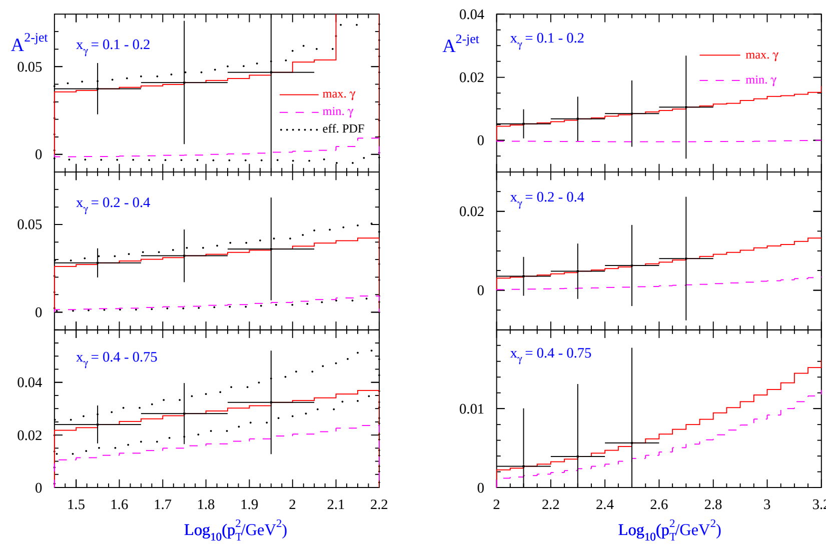

Figure 1: Predictions for $A^{2-\mathrm{jet}}$ in LO (left: eRHIC, right: THERA) using the two scenarios for Δf^γ as described above and the GRSV Δf^p densities[8]. Also shown are the expected statistical errors for such a measurement assuming 70% beam polarizations and $\mathcal{L} = 200\ \mathrm{pb}^{-1}$.

To actually unfold information on Δf^γ it is useful to introduce the concept of 'effective parton densities' [9]. Although $A^{2-\mathrm{jet}}$ is dominated by gg scattering, *all* QCD subprocesses contribute. In the unpolarized case it was shown [9] that the ratios of dominant subprocesses are roughly constant, i.e., $qq'/qg \simeq qg/gg \simeq 4/9$, such that the jet cross section factorizes approximately into some effective parton densities times a *single* subprocess cross section. In the polarized case this factorization is slightly broken as $qq'/qg \neq qg/gg$. However, the approximation still works surprisingly well at a level of $5-10\%$

accuracy, and the appropriate effective densities are given by [3] (see also ref. [10])

$$\Delta f_{\rm eff}^{\gamma} = \sum_q (\Delta q^{\gamma} + \Delta \bar{q}^{\gamma}) + \frac{11}{4} \Delta g^{\gamma} \tag{2}$$

such that the polarized double resolved jet cross section can be expressed as

$$\Delta\sigma^{2-{\rm jet}} \simeq \Delta f_{\rm eff}^{\gamma} \otimes \Delta f_{\rm eff}^{p} \otimes \Delta\hat{\sigma}_{qq'\to qq'} \ . \tag{3}$$

As can be inferred from the l.h.s. of Fig. 1, the effective parton density approximation (dotted lines) works very well indeed. It is only for large p_T that the deviations from the exact results become more pronounced.

Given the error bars shown in Fig. 1, the prospects for distinguishing between different scenarios for $\Delta f_{\rm eff}^{\gamma}$ are rather promising for eRHIC (but remote for THERA where only luminosities of $\mathcal{O}(10\ {\rm pb}^{-1})$ seem to be realistic) *provided* the $\Delta f_{\rm eff}^{p}$, also entering (3), are known fairly well, which is clearly not the case yet. However, our ignorance of the Δf^p will be vastly reduced by the upcoming polarized *pp* collider RHIC and ongoing efforts in the fixed target sector. It should be kept in mind that so far *nothing at all* is known about the Δf^{γ}, and even to establish the very existence of a resolved component also in the spin-dependent case would be an important step forward.

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